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ABSTRACT

Many are aware that to secure a safe Earth for future generations means that people must know more about the Earth, its inhabitants, and the role that each plays in sustaining life on Earth. This lack of knowledge today has led to decisions such as the destruction of the rainforest, the growing and inefficient use of fossil fuels, and until recently the continued use of chlorofluorocarbons (CFCs). In order to rectify this problem, many educators and scientists have suggested the development and implementation of school science programs that enfold the study of Earth systems. This paper provides a brief description of science education today, discussing the various influences on the development of a science curriculum, the need for Earth literacy, and the misrepresentation of the nature of science in curricula. More emphasis is placed on providing insight on an effort already in place to insure that science education reform in the United States will include planet Earth as a vehicle for teaching science. Educators are asked to seize this opportunity to provide students with knowledge that can be directly related to the world around them and hopefully provide an appreciation for the planet. (Contains 41 references.) (ZWH)

THE FUTURE OF THE GEOSCIENCES IN THE PRE-COLLEGE CURRICULUM

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Introduction

Earth Science Educators have an exceptional opportunity to achieve a long held dream; to have incorporated into their nation's school curriculum the concepts, processes and thinking characteristic of the various Earth science disciplines. In the United States several federal research agencies have cooperated in the development of the Earth System research program. Research scientists trained in different Earth science disciplines now work within this program, sharing their disparate backgrounds and skills, in conducting research on problems such as global climate change. This development provides a conceptual basis for the integration of important concepts about planet Earth in our science curricula.

Coupling with this initiative is the world-wide interest in restructuring science curricula which in the United States is represented by two major national programs. Both focus on the teaching of concepts from all science disciplines at all school levels. With Project 2061 of the American Association for the Advancement of Science, this takes the form of integrated science curricula. What would be more natural than to have the subject of all science, planet Earth, as the focus for such integrated curricula?

The Setting Today

In the wake of the political and economic changes in the former Soviet Union and the economic changes in the People's Republic of China, a new world order seems to be emerging where cooperation between nations will take the place of conflict. Electronic communication has made available an instantaneous flow of information between countries. Modern transportation has provided many people the opportunity of visiting countries that in the past were only seen on TV or in one's dreams. The world's citizenry must be enabled to participate in this new order through effective education that promotes the understanding of different cultures, that provides the skills to engage in communication and cooperation within and across national boundaries, and that develops an understanding of how the natural world works and how we can come to that understanding.

Political developments must not only foster the economic health and viability of nation states, but also provide the inter-state cooperation necessary to ensure a stable and healthy Earth environment in which to enjoy the fruits of economic development. We must come to understand the strengths and the limitations of the processes we use to learn about our Earth system and the implications they have for our use of technology. We must learn to balance the Western philosophy of controlling and exploiting nature with the Eastern philosophy of living in harmony with it.

As science educators, we have the responsibility to use our knowledge of the Earth, and of the nature of science, to construct effective future-oriented science programs that will be fundamental in assisting the world's citizenry to reach this new level of knowledge and understanding. Only through accomplishing these broad educational goals can we begin to attain and secure a quality standard of life for all the world's peoples. Our science education programs as they are now conceived and constructed, however, are poorly equipped to assist our students and future leaders to cope with the opportunities offered by the evolving new world order. They reflect closely the political development of science based largely in the industrial revolution of the 1800's, which in turn is based on the Western Judeo-Christian orientation toward controlling and using an otherwise hostile Earth environment.

Science Education Today

In our country, the major influence in the politics and conduct of science and subsequently how science is perceived by our citizenry has come from the physical scientists and engineers. It is they who have been asked over the years by our governments to provide the weapons of defense and environmental control; and now to develop the scientific understandings that will allow successful technical development to compete more effectively in the growing world economy. Consequently they have had a controlling influence over the nature and content of the schools' science curricula. For example; it was the fear of the military capability of the USSR that lead our National Science Foundation to fund curriculum development projects in the late 1950's. The physical science community led the efforts at both the high school and middle school levels setting the philosophy and standards for the development of new text materials and the teacher enhancement programs designed to support and implement those materials. Recently published biographies of physicists such as Luis Alvarez (1987), Nobel Laureate, document the role of the physics community in setting the scientific agenda in the United States leading up to, during, and following World War II. And that national scientific agenda, as it had throughout our scientific and technological history, determined the nature and content of the pre-college science curricula.

The Need for Earth Literacy

Revelations of environmental devastation in the countries emerging from communist rule coupled with the growing scientific evidence of ozone depletion and global warming have focused attention on world-wide problems of degradation of the world's climate, water and land. This attention and consequent concern provides the Earth science education community with an unparalleled opportunity to exercise leadership in developing science education programs designed to enhance the knowledge of our planet. To secure an Earth that is habitable and productive for future generations we must have scientists, engineers, economists, politicians and industrialists who understand the relationships between the processes scientists have identified and engineers have harnessed for economic and defense purposes, and the Earth subsystem from which they were derived. Can this now be the case when industrialists, encouraged by their chemists and engineers, until recently recommended the continued use of CFCs and the growing and inefficient use of fossil fuels? Of course not. If our business and political leaders were Earth literate and thus understood the relationship between species diversity and the well-being of the biosphere with its implications for future human health and long-range economic stability, we would not be destroying the rain forests of the American Pacific Northwest for short range employment, economic and political benefits. Nor would our political leaders forsake long-range energy policies that would reduce our extravagant use of fossil fuels and the consequent contributions to global warming.

Certainly there is need for school science programs that more effectively develop knowledge of Earth systems among the citizens and the future scientific, industrial and political leaders of the world. And there is a special need for secondary school science curricula that develop such knowledge. It is here in our world's secondary schools that future political, business, and yes, science leaders must encounter Earth systems concepts at a level of sophistication that would support their utilization in the policies developed by these future leaders; and by the educated citizenry who would then be enabled to encourage and accept the adoption of such policies.

Misrepresentation of the Nature of Science in Curricula

The history of the development of our science establishment is intimately intertwined with perceived needs for military, defense and industrial applications. Funding for research, whether from national treasuries or from industrial coffers, has in most countries invariably been tied to the demonstration of short-term benefits to the economy, defense, or international status (Kevles, 1987). This has had a major impact on the type of science that has been conducted throughout the world. One result has been the emphasis upon a deterministic and reductionist paradigm for science where the isolation and study of specific utilitarian physical or biological processes has been the major goal of investigation. Although the initial observation and description of phenomena has been fundamental in this process, the primary emphasis is on the study of selected phenomena through rigorously controlled experimental techniques.

The relatively vast amount of political and financial support available to this phase of science contrasts dramatically with the neglect of the historical and descriptive methodologies. They are not perceived as producing the economic and military benefits of the "hard" science approach. After all, of what practical use is an understanding of the evolution of trilobites or of the development of continents and ocean basins? Of what strategic or economic benefit is the evidence and concern about global warming? In fact, however, they are important. The knowledge that has had the most far-reaching impact on our intellectual and cultural lives has been the result of investigations using historical and descriptive methodologies. It includes the heliocentric solar system, the expanding universe, organic evolution, deep time, plate tectonics, and most recently, global climate change.

The science community is now in great flux because of the rapidly emerging understanding of the complexity of Earth systems. The "hard" science approach has been unable to provide adequate insight into the complex processes of the Earth systems, illustrating the severe limitations of reductionist science for studying processes as they occur in the real world. This has perplexed the physicists. As a result chaos, a mathematical theory born in the 1960's in large part from Edward Lorenz's attempts to produce more accurate weather forecasting models, has seized the mathematical and scientific communities with what may become the major scientific revolution of our time (Gleick, 1987). In recognizing the vast complexity of Earth systems and the negative impact of feed-back processes within systems on the potential for prediction, chaos theory has the power to change how scientists view not only the world in which we live but how we think about it and how we investigate it.

Little of the excitement of science enters our classrooms, and little of its fascinating complexity as illustrated by chaos theory, earthquake or weather prediction, or the historical development of continents is afforded our brightest secondary school students. Instead, the nature of science continues to be inaccurately portrayed in every classroom in the world. Elementary, middle school and high school students learn that unless a person does experiments she is not a scientist. Steven Gould commented on this deep seated bias against the historical sciences in his article, *Evolution and the Triumph of Homology, or Why History Matters:*

> Historical science is still widely misunderstood, under-appreciated, or denigrated. Most children first meet science in their formal education by learning about a powerful mode of reasoning called "*the* scientific method." Beyond a few platitudes about objectivity and willingness to change one's mind, students learn a restricted stereotype about observation, simplification to tease apart controlling variables, crucial experiment, and prediction with repetition as a test. These classic "billiard ball" modes of simple

> physical systems grant no uniqueness to time and object--indeed, they remove any special character as a confusing variable--lest repeatability under common conditions be compromised. Thus, when students later confront history, where complex events occur but once in detailed glory, they can only conclude that such a subject must be less than science. And when they approach taxonomic diversity, or phylogenetic history, or biogeography-- where experiment and repetition have limited application to systems in toto--they can only conclude that something beneath science, something merely "descriptive," lies before them (Gould, 1986).

The misrepresentation of science that pervades the science curriculum bears bitter fruit in the misunderstanding rampant among the world's public about those who conduct science and of the nature and importance of the research performed by Earth scientists. The commonly held image of science is that of controlled laboratory experiments conducted by a balding and perhaps bearded Englishman wearing a white lab coat. Every component of this image is, of course, wrong. Where, for example, is the African geologist in her field clothes represented in the common image of the scientist? Or the Asian oceanographer studying thermal vents from a submersible? The lack of understanding of basic Earth systems concepts and methods is evidenced by the lack of objectivity among the political and business leadership when confronted by issues such as acid rain, global warming or deforestation. And yes, among some physicists and engineers as they denigrate the results of Earth science research as something less than science.

Science Curriculum Ignores Planet Earth

Few national science curricula have included Earth science in the high school science curriculum. There are some exceptions such as the countries of Venezuela, Korea and Taiwan where Earth science is included in the science track. But even in these cases it is given half as much time as each of the other disciplines; physics, chemistry and biology. A recent review of the literature found a number of other countries where Earth science is included in secondary school science programs. It appears that there is a Geology or Earth Science component under development for the "A" level syllabus in Great Britain (Dineley, 1990). The State of Victoria in Australia provides a certificate of education in geology for senior high school students. That course of study has recently been revised (Markovics, 1990). In Japan, there are thirteen science courses offered in the new revised edition for the science course of study in the upper secondary schools. Four are Earth science and one integrated science which includes some Earth science content (Sakakibara, 1992). In contrast in The People's Republic of China, students expecting to go on to college must take a science examination, however, there is no Earth science content on that examination (Butler, 1986). In the former Soviet Union, Earth science content was included in physical geography courses offered in grades 6 through 8. From 9th grade on, however, only regional, social and economic geography was required (Maksakovsky, 1989). With the exception of the countries cited above, there seems to be little recognition at the international level, of the importance of a background in Earth science concepts for the future leaders of the respective countries.

This conclusion is reinforced by international studies of students performance in science. Two studies in science have been conducted by the International Educational Assessment. The first was completed in 1973 (Comber and Reeves, 1973) and the other in the late 1980's (IEA, 1988). Neither assessed Earth science knowledge because the study coordinators determined that there wasn't sufficient teaching of Earth science at the high school level in the world's schools to merit measurement.

In the United States the situation, despite the strong efforts of the Earth science education community over the past 20 years, is equally dismal. According to surveys conducted by Iris Weiss (1987) less than three percent of our nation's senior high school students have the opportunity of taking a course in Earth science or one of the individual Earth sciences. This might not be a problem, if the concepts of the Earth sciences were covered in the traditional physical science courses; chemistry and physics. A recent analysis of the most-used American textbooks in those subjects, however, revealed that *Chemistry*, published by Heath in 1987, had less than 25 pages of a total of 670, devoted in some way to the mention of the Earth system. Chapters 1 and 2 which dealt with water and energy did not contain a single substantive reference to an Earth subsystem. *Physics*, published by Merrill (1986) had only five pages of a total of 549 which dealt somehow with an Earth subsystem. *Conceptual Physics* (Addison Wesley, 1987) did much better, but still only 26 pages of a total of 622 dealt with the Earth system. I suspect that analysis of science texts from other countries will yield a similar pattern of neglect. If the topics are not covered in the textbook, then they are most likely not being covered in the courses in physics and chemistry.

Why do we have such uniform neglect of Earth science around the world? Here and around the world, the key individuals who determine the science curriculum are physics educators. For example, in the United States they include James Rutherford and Bill Aldredge, in Great Britain, Paul Black, in Korea, Jae-Sool Kwon and in Taiwan, Chin Chi Chao. Each of these individuals have had their primary science training in physics. Just as the physicists have been most influential in the politics of science, so have the physics educators been most influential in the establishment of science curriculum. And naturally they emphasize what they know and respect best.

Little is being done in the secondary schools of the world to acquaint our future citizens with Earth system concepts and processes. Our future scientists, politicians, economists and business leaders do not have an opportunity, therefore, to take a science course offered at the level of sophistication appropriate for bright secondary school students that would inform them about the planet on which they live. Can we accept this situation? I for one can't. What can we do about it? We must take leadership in the development of integrated science curriculum.

Earth Systems Education: A Movement Toward Solution

In the past twenty years there have been tremendous advances in the understanding of planet Earth from the application of high technology in data gathering by satellites and data processing by supercomputers. As a result, Earth scientists are in the process of reinterpreting the relationships between the various subdisciplines and their mode of inquiry. These changes are documented in the "Bretherton report," developed by a committee of scientists representing various American government agencies with Earth science research mandates (Earth System Sciences Committee, 1988). This reconceptualization of the process and goals for study of planet Earth has been termed Earth System Science. It provides a conceptual basis for rethinking the fabric and organization of the total K-12 science curriculum.

The Bretherton Report organizes Earth systems understandings on two time scales. One set occurs on a scale of millions of years and is illustrated by processes such as plate tectonics and organic evolution. The other occurs on the time scale of decades and centuries and is illustrated by global warming and acid rain. These latter changes are dramatically influenced by the world's human population, an ever more influential component of the biosphere. An understanding of these short-term global changes is essential for the health of future generations of humans and of the planet as a whole. Understanding the long-term changes are essential for establishing philosophically our place in the world and how it and we arrived here. Therefore there is a powerful case for making the Earth System a central organizing theme for future K-12 science curriculum development. There is another reason as well. Science, after all, is fundamentally our attempt to understand our habitat and how we came to be a part of it. In other words, our attempt to understand our Earth system. The concept maps developed in the report can provide a foundation for selecting and organizing those science concepts that are important for all the world's citizen's to understand.

Rethinking the Science Curriculum

Project 2061, of the AAAS, is the major attempt in the United States to lay the basis for a revision of the content of the K-12 science curriculum. Its report, entitled *Science For All Americans*, is heavily influencing curriculum restructure (AAAS, 1989). Phase I of Project 2061 was being developed about the time of the publication of the Bretherton report. It's goal was for the science community to identify for educators those essential concepts and "habits of mind" that every scientifically literate citizen needed to understand to live productively in modern society. It was intended that these concepts would then be the content for the new curriculum. None of the scientists working on the Bretherton report were involved in Phase I of Project 2061. Little of their thinking about the nature of science and the planet that is its most important subject is contained in *Science for All Americans*. In the minds of many, this failure to include a central role for planet Earth is a serious omission from documents that may very well determine the future shape and content of science curriculum in the United States, and perhaps elsewhere in the world.

When it became clear that curriculum restructuring efforts in the United States might again ignore planet Earth and focus on the deterministic and reductionist model of science, a conference of geoscientists and educators was organized and took place in Washington, DC in April, 1988. The forty scientists and educators, including many scientists from the agencies responsible for the Bretherton Report, met over a period of five days. Through small group interaction techniques they developed a preliminary framework of four goals and ten concepts from the Earth sciences that they felt every citizen should understand (Mayer and Armstrong, 1990). Through the work of the conference participants and subsequent discussions with teachers and Earth science educators at regional and national meetings of the National Science Teachers Association, a new focus and philosophy for science curriculum emerged under the label, Earth Systems Education.

In Spring of 1990, the Teacher Enhancement Program of the National Science Foundation awarded a grant to The Ohio State University for the preparation of leadership teams in Earth Systems Education--PLESE, the Program for Leadership in Earth Systems Education. The objective of the program was to infuse more content regarding the modern understanding of planet Earth into the nation's K-12 science curricula. In preparation for this program, the PLESE planning committee met in Columbus in May, 1990, to develop a conceptual framework which would be used to guide the content and philosophy of the program. Input for their work included the Project 2061 report and the results of the April, 1988, conference. Over a period of five days the committee developed a Framework for Earth Systems Education consisting of seven understandings. These understandings provided a basis for the PLESE teams to construct curriculum guides for their areas of the country and for selection of existing materials for implementing Earth systems education in their areas.

The Earth Systems Education Framework (Mayer, 1991) also has implications for the development of integrated science curricula. The first understanding emphasizes the aesthetic values of planet Earth as interpreted in art, music and literature (Mayer, 1989). It stresses the creativity of the human spirit and how that creativity has perceived and represented the planet on which we live; a creativity that is also essential to the proper conduct of science. An appreciation of the Earth system naturally leads the student into a concern for the proper stewardship of its resources; the second understanding of the framework. Carpenter (1990) has made a powerful argument as to why the environmental aspects of the Earth sciences should be central to pre-college science teaching. A developing concern for conserving the economic and aesthetic resources of our planet leads naturally into a desire to understand how the various subsystems function and how we study those subsystems; the substance of the next four understandings. The last understanding deals with careers and avocations in science bringing the focus once again back to the immediate concerns and interests of the student.

Integrating the Science Curriculum

There seems to be strong movement toward reducing the emphasis upon the distinctions between the science disciplines in the ongoing science curriculum renewal effort in the United States and elsewhere throughout the world. This is clearly the goal of the Project 2061 recommendations, most easily interpreted as a call for an integrated science curriculum. It has certainly been a long-term goal of the international science education community. The first time I visited England was to present a paper at a UNESCO conference on Evaluation of Integrated Science Teaching held in Oxford (Mayer and Richmond, 1977). That was almost twenty years ago. It was only one of several UNESCO efforts spanning a number of years. They resulted in a series of publications on integrated science curricula. In the United States there were several attempts such as the Unified Science movement during the 1960's and early 70's, to implement integrated curricula. Most of these efforts have all but vanished as the teachers involved in the original development and implementation efforts moved on to other ideas or retired.

What all of the attempts to integrate the science curriculum in the past have lacked was a conceptual focus. The logical focus for a new integration effort is the Earth system. In essence, science is a study of planet Earth; our attempt at understanding how we got here and how our habitat works. What could be more natural than developing a K-12 science curriculum using the subject of all science investigations--planet Earth--as the unifying theme? Any physical, chemical, or biological process that citizens must understand to be scientifically literate, can and should be taught in the context from which the particular process was taken for examination: its Earth subsystem. That is the major implication for Earth Systems Education and its potential impact on science curriculum reform efforts.

Let's take a look at the Earth Systems Education Framework with the idea of integration in mind. Understanding Two allows a great deal of latitude for the popular trend toward Science, Technology and Society (STS) emphasis in science curriculum, as does Understanding Three. Understanding Three encourages the teacher to develop an understanding of the historical and descriptive science methodologies so essential to the Earth sciences. But it also includes the reductionist methods of the chemist and physicist. Several of the Understandings include opportunities for basic physics and biology. An understanding of time, also emphasized by Carpenter (1990), is the focus of Understanding Five. These are just samplings of how the understandings can be used as a philosophical guide for the development of integrated science curricula. We are now in the process of developing detailed

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curriculum frameworks for both the middle school and high school level.

Earth Systems Implementation Efforts

The first project to test aspects of the Earth Systems Education thrust has been an integrated Biological and Earth Systems (BES) science sequence developed by the Earth Science and Biology teachers of a central Ohio school district to replace their 9th grade Earth science and 10th grade Biology courses. The sequence is organized around basic issues concerned with the Earth system; such as global climate change and deforestation. The program incorporates collaborative learning and problem solving techniques as a major instructional strategies. Current technology is also integrated into the course sequence including the use of on-line and CD-ROM data bases for accessing current scientific data for use in course laboratory instruction (Fortner, et al, 1992).

A second effort is now underway, also in central Ohio. Ten school systems, including the two largest, have each designated a team of three to five middle school teachers to participate in a collaborative school-university program to study the implications of Earth Systems Education philosophy and methods for the restructuring of their middle school science curricula. Four of the teams have developed a draft syllabus for their school districts and two have implemented portions of the syllabus. Other efforts are now underway in New York and Colorado.

On the world scene there have been few such developments. The exception is from the CENEMEC in Venezuela. They have used an Earth Systems approach in the revision of the national curriculum guide for the secondary school Earth science course (Coordinacion de Ciencias de la Tierra, 1992). So far this is the only international attempt at an Earth systems construct that has come to my attention.

Conclusion

We have inherited a national and world orientation toward the reductionist paradigm exemplified by the traditions of the physical sciences, both in our science curricula and in how we think about national development. The application of this orientation has been highly productive in serving the needs of the "old order". It has provided the scientific basis of military technology and growing, technically based national economies. The existing science curriculum reflects this orientation. Just take for example the many processes of science that have been identified as separate entities in problem solving. In an elementary science project that I worked on, over 15 different processes of science are identified, including inferring, hypothesizing, classifying, experimenting and graphing. This is a clear application of reductionist science philosophy to science curriculum development.

The current curriculum ignores the contributions of the descriptive and historical paradigms of science. Yet it is these sciences, geology, paleontology, biology, that have provided us with the knowledge behind the theories of evolution, deep time, and a heliocentric solar system that have profoundly influenced our understanding of our place in the universe. It is these sciences that are also giving us a view of the future. Where our dependence upon the reductionist paradigm and its technical products are taking us. Global climate change. Acid rain. Deforestation. Overpopulation.

We must rethink the entire basis of the content of the science curriculum and the reductionist philosophy of science that undergirds it. We are evolving into a new world order, where the old standards can no longer apply. We cannot continue with a science program based on the successes of the past. We must look to the future. What are the critical needs of our world society. Are they really found in more efficient production of cars? Supersonic transports? More energy production? We need to have a science that helps us understand global climate change and our contributions to it; the role of rain forests in global ecology; the nature of the human species; how we can improve its health. These are the challenges. Reductionist science can only help us marginally in creating the understandings, and in valuing those understandings.

Also, we now know more about how children learn science. A topic I have avoided here simply because of space restrictions. British researchers such as Rosalind Driver tell us that students come to us already familiar with the natural world, having constructed frameworks based upon their experiences. These naive theories can either block or facilitate their learning of the scientific conceptions of natural processes. This has serious ramifications for the construction of the New Science Curriculum. This information has not come from the reductionist approaches applied to research in science education, but to the more informal historical/descriptive approaches, the qualitative paradigms that are much more productive in studying issues as complex as how children learn science.

The time appears to be ripe for the first total restructuring of the science curriculum since the late 1800's. The dramatic changes that have taken place in science and in the understanding of how science is learned, and the evolving demands of technology and the pressures it places on our environment require this restructuring. We must develop a citizenry and a cadre of leaders who are comfortable with science and knowledgeable about the role it plays in understanding our Earth system. They need to understand the applications of science in technology and the role technology plays in our society, in science and in changing our Earth systems. Integrated science programs focusing on the Earth System as their integrating theme, combined with a constructivist approach to learning, would offer an effective approach for reaching these objectives long held as being important curricular objectives by Earth science teachers. They would effectively serve the objectives of scientific literacy and at the same time provide a basis for the recruitment of diverse talent into science and technology careers helping to ensure appropriate economic development consistent with maintaining a quality environment. As Earth science educators we must take the leadership in developing and establishing integrated science curricula in which the Earth system plays the central and key role.

A Personal Postscript

As Earth systems students and teachers we study Earth processes and how they affect us and a variety of natural features such as landscapes. A dramatic example is the lava flows now emanating from the flanks of Muana Loa, constructing new land for the Island of Hawaii. Into these natural processes, however, we have introduced a new factor ourselves and our activities.

Because of the tremendous power we have accumulated through science and technology to influence our natural Earth system processes, and in our press to revise curriculum to help our respective countries achieve further technical development and a bright economic future we must reflect carefully upon Harrison Brown's concerns expressed so eloquently over 20 years ago. He said:

> The machine has divorced us from the world of nature to which we belong, and in the process we have lost in large measure the powers of contemplation with which we were

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endowed. A prerequisite for the preservation of the canons of humanism is a reestablishment of organic roots with our natural environment and, related to it, the evolution of ways of life which encourage contemplation and the search for truth and knowledge. The flower and vegetable garden, green grass, the fireplace, the primeval forest with its wondrous assemblage of living things, the uninhabited hilltop where one can silently look at the stars and wonder -- all of these things and many others are necessary for the fulfillment of humankind's psychological and spiritual needs. To be sure, they are of no "practical value" and are seemingly unrelated to our pressing need for food and living space. But they are as necessary to the preservation of humanism as food is necessary to the preservation of human life. (Brown, 1954)

When teaching about planet Earth we must plan learning activities that engage the right brain as well as the left brain as we involve our students in a study of science. We need to develop in our children, both a knowledge and an appreciation of this planet that has been our home. Students should encounter planet Earth through our integrated science courses as a thing of beauty; its processes developing spectacular vistas as they operate over eons of time. Our students should be able to marvel at the beauty of an ice crystal sparkling in the sun as a glacier melts. They must come to value the Earth, not just for the minerals it gives up to industry, or the oil it provides for our cars, but for the sunsets from its atmosphere and the symmetry in a crystal. As Earth systems teachers help their students achieve a rational understanding of the Earth and its processes they will also provide a firm foundation for international cooperation on Earth's problems such as global warming, acid rain, and political instability.

In encouraging our students' aesthetic appreciation of the Earth, we will provide them new avenues for enjoyment. Our goal must also be the development of a system of values that honors the enduring spirit of humankind as it strives for equality of rights and that recognizes its dependence upon the aesthetic qualities as well as the resources of planet Earth. Perhaps then we will have a world citizenry that values our Earth systems and through its political power implement in each of the countries of the world, economic and political practices that will guard the integrity of those systems for our benefit and the benefit of future generations of citizens of this our one and only planet.

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